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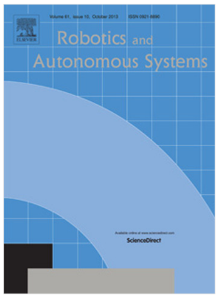

Adaptive synthesis of dynamically feasible full-body movements for the humanoid robot HRP-2 by flexible combination of learned dynamic movement primitives

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Adaptive synthesis of dynamically feasible full-body movements for the humanoid robot HRP-2 by flexible combination of learned dynamic movement primitives

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Abstract

Skilled human full-body movements are often planned in a highly predictive manner. For example, during walking while reaching towards a goal object results in steps and body postures are adapted to the goal position already multiple steps before the goal contact. The realization of such highly predictive behaviors for humanoid robots is a challenge because standard approaches, such as optimal control, result in computation times that are prohibitive for the predictive control of complex coordinated full-body movements over multiple steps. We devised a new architecture that combines the online-planning of complex coordinated full-body movements, based on the flexible combination of learned dynamic movement primitives, with a Walking Pattern Generator (WPG), based on Model Predictive Control (MPC), which generates dynamically feasible locomotion of the humanoid robot HRP-2. A dynamic filter corrects the Zero Moment Point (ZMP) trajectories in order to guarantee the dynamic feasibility of the executed behavior taking into account the upper-body movements, at the same time ensuring an accurate approximation of the planned motion trajectories. We demonstrate the high flexibility of the chosen movement planning approach, and the accuracy and feasibility of the generated motion. In addition, we show that a naïve approach, which generates adaptive motion by using machine learning methods by the interpolation between feasible training motion examples fails to guarantee the stability and dynamic feasibility of the generated behaviors.

Keywords:
robotics, navigation, walking pattern generator, goal-directed movements, movement primitives, motor coordination, action sequences

1. Introduction

The modeling and the synthesis of the online-reactive multi-action sequences is an extremely important topic in both, computer graphics and humanoid robotics. The most challenging problem in the online control of complex whole-body behaviors, which is solved apparently effortless by humans, is the flexible coordination of goal-directed movements with the maintenance of dynamic balance during locomotion. The solution of this problem requires simultaneously the flexible adaptation of executed upper-body behaviors, e.g. to changing positions of goal objects or obstacles, combined with a control of dynamic balance during walking, in order to avoid that the robot falls. In addition, the robot's joint torques have to be kept in a feasible range. The detailed analysis of human behavior shows that their motor control is highly predictive, and often optimizes complex behaviors over long time horizons, e.g. lasting over multiple steps. This is fundamentally different from many solutions of this problem in humanoid robotics [Siciliano and Khatib (2016)].

The realization of such complex behaviors for humanoid robots with long time horizons for predictive control is a challenging problem. A standard method for the computation of control signals for such high-

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